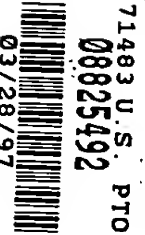# APPLICATION FOR UNITED STATES LETTERS PATENT

for

SCHEME FOR MERGING PARTIALLY FILLED ATM CELLS

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SCHEME FOR MERGING PARTIALLY FILLED ATM CELLS

FIELD OF THE INVENTION

5   The present invention relates generally to the field of cell switching network communications and, more specifically, to the merging of data information contained in multiple partially filled cells transported across such a network into a single cell to enable efficient use of available bandwidth.

10   BACKGROUND

The desire to integrate data, voice, image and video over high speed digital trunks has led to the development of a variety of packet and cell switching techniques. One such technique is called Asynchronous Transfer Mode (ATM). ATM is a switching technology that provides users with the ability to connect to one or more users in a transparent fashion.

15   Unlike the variable length packets used by frame relay services, ATM service is based on switching fixed length packets of data known as cells. Cell switching, as it is called, is gaining popularity for a variety of reasons. First, switch architectures can be optimized to switch cells at much higher speeds than variable length packets. Second, multiple services requiring a variety of quality of service guarantees can be provided simultaneously. ATM

20   user traffic is first segmented into fixed length cells, transmitted, then reassembled back into its original form. This segmentation and reassembly (SAR) process is done in a standardized way, regardless of the carrier providing the ATM service.

Although the use of fixed length cells in ATM can be efficient in terms of allowing standardized switching apparatus to be used, for many applications the standard 53-byte

25   cell provides too large a package for the data requiring transport through the network. As a result, much of the cell payload is merely "padding" and the transport of such padding

wastes the available bandwidth of the ATM network. Several approaches to solve this problem present themselves.

For example, one could use a shorter length cell. As indicated, ATM uses a standard 53-byte cell, with 48-bytes of payload and 5-bytes of header information.

5   Choosing a smaller cell size could result in less of the cell payload being filled by padding. However, shorter cells have two important disadvantages. First, such cells would be non-standard and, as a result, such cells could not be transported through ATM networks designed to accommodate only standard size cells. This lack of interoperability would likely mean that users would be disinclined to accept such a solution. Second, smaller cells

10   would likely end up wasting more bandwidth than they would save because the ratio of header size to payload is much higher than for a 53-byte cell. Unfortunately, the header size could probably not be reduced from the current 5-byte size without a loss of functionality.

Another solution might be to use variable length packets, as is common in frame

15   relay networks. This could conceivably avoid the need for padding altogether because packets could be "custom built" to the requirements of the user data. Unfortunately, the very fact that such varying packet sizes are allowed within frame relay networks means that the switches used to transport the packets across the network must be more complex than their ATM counterparts. As a result, such switches are generally slower than ATM

20   switches. Further, in networks where variable length packets are used, it is difficult to make real time service guarantees without the use of complex servicing and queuing algorithms and some limitations on packet size.

Yet another solution might be to pack multiple payloads into one cell at a source and then pull these payloads apart at a destination. The ATM Forum has begun discussions

25   regarding such bundling of data channels within a single cell, however, it is recognized that this will only provide a solution for channels which have the same source and destination nodes. For example, referring to Figure 1, multiple calls from end-system A to end-system

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B could be bundled together, but such calls could not be bundled with calls from end-system C to end-system D, even though they share a network trunk between switches 5 and 10. This results in less than ideal efficiency and also requires higher layer signaling support to assign slots in each cell to various channels and to manage the slot allocation

5   across a network. Possibly, switches 5 and 10 could provide a server functionality which terminates all virtual channels (VCs) and swaps around sub-channels to improve efficiency on the network link between the switches. However, this solution would introduce significant complexity in switches 5 and 10 because the switches would now be required to understand the end-to-end channel assignments and pack and unpack data from many cells

10   simultaneously. Besides the increased hardware complexity required for this function, the signaling and management of the reassignment of sub-channels would require complicated signaling.

Accordingly, what is needed is a scheme for ensuring that as much available payload space within the fixed length cells of ATM networks are used to transport user data

15   rather than padding without resulting in the drawbacks of the methods described above.

SUMMARY AND OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to provide a method for merging two or more partially filled ATM cells into one merged ATM cell.

It is an additional object of the present invention to allow for splitting payload data in a merged ATM cell into two or more partially filled ATM cells.

These and other objects of the invention are achieved, in one embodiment, in a method for merging partially filled ATM cells in which first and second partially filled ATM cells are removed from a cell stream and merged into a third ATM cell. The third ATM cell may then be inserted back into the cell stream. The third ATM cell may include header information indicative of the number of partially filled ATM cells from which it was created.

In a further embodiment, a data communication device, such as an ATM switch, includes means for identifying partially filled ATM cells within an ATM cell stream. The device also includes means for merging at least two of the partially filled ATM cells into a merged ATM cell and means for inserting the merged ATM cell back into the ATM cell stream. The means for identifying partially filled ATM cells may comprise a lookup table stored in a computer readable medium and indexable using logical connection identification (e.g., VC) information.

The present invention can be used on a link-by-link basis within an ATM network or across multiple hops within such a network for combining cells traveling along a common route. The present invention is not limited to combining information on the same virtual channel or information which travels only between a common source and destination. The method maintains the use of standard ATM cells and so is compatible with existing and future ATM equipment. Other objects, features and advantages of the present invention will be apparent from the accompanying drawings and from the detailed description which follows.

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BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements, and in which:

5   Figure 1 illustrates a cell relay network having four end-stations and two switches with multiple calls routed between various end-stations;

Figure 2 illustrates the merging of two partially filled ATM cells into a single merged ATM cell according to one embodiment of the present invention;

Figure 3 illustrates the use of cell splitting and merging functions within various

10   nodes of an ATM network according to one embodiment of the present invention; and

Figure 4 illustrates the use of cell splitting and merging functions within end-nodes of an ATM network according to one embodiment of the present invention.

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<u>DETAILED DESCRIPTION</u>

A method and apparatus to allow merging/splitting of partially filled ATM cells into/from a single merged ATM cell is described. According to one embodiment, partially filled ATM cells passing through a node of an ATM network are removed from an ATM

5   cell stream and merged into a single ATM cell. The single, merged ATM cell may then be inserted back into the cell stream. Header information in the single, merged cell may be used to indicate the number of partially filled cells which were used to construct the single, merged cell.

As shown in Figures 2-4, a means of combining payloads on different virtual

10 channels (VCs) into a single cell is provided. A "merging" function is provided at a transmitting end of a link in an ATM network and a "splitting" function is provided at the receiving end of the link. These functions are provided below the ATM layer so that the operations are transparent to switches (such as switches 15 and 20 in Figures 3 and 4), end-systems (such as systems A, B, C and D in Figures 3 and 4) and signaling and

15 application software.

Figure 2 illustrates the essence of the merging and splitting functions provided at the ends of a transmission link. Partially filled ATM cells 30 and 32 are removed from a cell stream 34 at any node (e.g., a switch or and end-system) of an ATM network. The cell stream 34 also includes filled cells 36. The partially filled cells 30 and 32 are merged

20 together (headers and payloads) into a single merged ATM cell 38 with a new header 40, and the new merged cell 38 is then reinserted back into the cell stream 34. Figure 2 shows the case where two partially filled cells are merged into a single cell, however, it should be appreciated that other numbers of cells could be similarly merged, so long as the resulting cell maintains the 53-byte size of a standard ATM cell. Header 40 contains all of the

25 information necessary to reconstruct the original cells 30 and 32 at a receiving end. This may include, for example, the number of partial cells contained in the merged cell,

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delineation information indicating the boundaries of the original cells in the merged cell, etc.

The merging algorithm works by holding a first partially filled cell until the next partially filled cell arrives. The user data and headers from the two partially filled cells are then merged into a single cell. If the second partially filled cell does not arrive within a preset time interval, then the first partially filled cell could be reinserted back into the cell stream unaltered so as to avoid lengthy delays and/or out-of-order cell transmission. During reception, a splitting algorithm recognizes (e.g., from the header information) a merged cell and splits the payloads and headers of the two partially filled cells back into separate cells which are then reinserted in the cell stream.

Many different merging schemes could be used. For example, a simple system might have fixed positions for n, 48/n-byte sub-cells. That is, if n represents the number of partially filled ATM cells to be merged into a single cell (n = 2 in Figure 2), then a system could allocate fixed positions for n such cells, each having 48/n bytes, within the single merged cell to be produced (e.g., 48/2 = 2 x 24-byte cells for the example shown in Figure 2).

A more elaborate indexing scheme for multiple sub-cells of different lengths could also be used. In such a scheme, payload byte 1 of the merged cell might accommodate the length, l1, of partially filled cell 1 (user data and header); payload bytes 2 to l1+1 would then carry cell 1; payload byte l1+2 would accommodate the length of cell 2,; payload bytes l1+3 to l1+l2+2 would then contain cell 2; and so on. To improve packing efficiency in either of these schemes, the header error correction (HEC) byte in the merged headers may be dropped. Also, it may be desirable to limit the VPI/VCI space in the merged cell headers to less than 28 bits. To provide protection, an error control byte for the entire merged cell could be provided.

The VCI of the merged cell (shown as VCI = c in Figure 2, where the partially filled cell 30 had original VCI = a and partially filled cell 32 had original VCI = b) could be

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used to represent the merging method. Thus, multiple merging methods could be supported on a single link. For example, VCI = 32 could be used to indicate that two cells are merged while VCI = 33 could be used to indicate that three cells are merged, and so on.

When the cells are split at the receiving end, the unused bytes in the resulting

5   partially filled cells must be padded. The value or method used for padding could be indicated by the VCI or conveyed as a coding in the merged cell payload.

The splitting and merging functions described above may be part of the physical convergence sub-layer so that the functions are transparent to the layers above. The functions can be deployed on a link by link basis within a network. As shown in Figure 3,

10   any short payload traffic traveling on the link between switches 15 and 20 could be merged, regardless of the end-to-end path. Similarly, any traffic on the link between end-system C and switch 15 could also be merged, regardless of the end-to-end path. Notice that where link by link merging and splitting is performed, the end-nodes of the merging/splitting operation carry out complementary functions. That is, for traffic between

15   switches 15 and 20, if a merging operation is performed at switch 15, a complementary splitting operation is performed at switch 20, and vice-versa. Also, if a merging function is performed at end-system C, a splitting function will be performed at switch 15, and so on. Traffic on other links in the network illustrated in Figure 3 would travel as in a conventional ATM system.

20   As extensions of the example illustrated in Figure 3, the splitting/merging operations may be used to operate over virtual links, i.e., virtual paths (VPs) tunneled through switches without the merging or splitting functions. Note that for this approach, only cells traveling through the same tunnel can be merged. This could be identified by matching VPs or by use of a unique cell tag match, internal to the switches or end-systems.

25   Alternatively, the merging/splitting operations could be provided only on an end-to-end basis, if it is possible to identify which VCs are traveling on a common path. An example of this approach is illustrated in Figure 4. End-systems B and C are configured

with means to provide merging and splitting operations as described above. Traffic between end-systems B and C is passed between switches 15 and 20, neither of which are configured to provide merging/splitting operations. Merged traffic between end-systems B and C is passed between switches 15 and 20 in the same manner as any other ATM traffic

5   because the merged cells maintain the standard ATM cell profile. When the merged cells reach a destination end-system, a splitting operation is performed and individual, partially filled cells are created. This example applies to cells traveling on the same end-to-end path, which could be identified using a cell tag match system internal to the end-systems.

It should be appreciated that the merging and splitting functions could reside at the

10   inputs and outputs of a switch, be incorporated into a switch, or reside in an adjunct server module. However resident, the operations require a means to identify which cells are partially filled. This could be achieved in a variety of ways. For example, a table of bits (e.g., a lookup table)indexed by connection number or VCI/VPI indicating whether or not a connection can be compressed (i.e., merged). This would be suitable for applications such

15   as compressed voice where virtually every cell contains only a partially filled payload. Alternatively, a new PTI (e.g., PTI = 7) could be used to convey that the cell has a partially filled payload and is eligible for a merging operation. Further, partially filled cells could be identified by looking at AAL information, e.g., finding single cell AAL5 frames. Of course, other means of identifying partially filled cells are possible.

20   It will be appreciated that the merging and splitting operations could violate cell sequence integrity when a single virtual channel contains some partially filled cells and some fully packed cells. This can occur, for example, when partially filled cells are removed from a cell stream, e.g., in a switch, and a fully packed cell on the same virtual channel is passed while the partially filled cell is held, awaiting another partially filled cell

25   to arrive. This problem can be avoided by checking for a match between the VPI/VCI of waiting partially filled cells and the VCI/VPI of fully packed cells which are passing by. When a match is detected, the partially filled cell(s) having the matching VCI/VPI is/are

reinserted into the cell stream and scheduled before the fully packed cell, to avoid cell out-of-order transmission.

The merging/splitting operations discussed above improve the efficiency of the transport of short pieces of data while retaining the benefits of the ATM standard cell size.

5   For compressed voice applications, it is believed that these operations can achieve transport efficiency over existing methods on the order of 2 to 4 times. Existing and future standard ATM switches and end-systems can accommodate these merging and splitting operations because the operations are transparent to the ATM level. The methods may be employed on a link by link basis and, therefore, there is no need for a network-wide equipment upgrade

10   when some components are configured in accordance with the present invention. It is recognized that these methods may require a switch core to drive a merging unit and/or accept cells from a splitting unit at up to "n" times the link rate (where n = the number of partially filled cells to be merged into a single, merged cell). This may cause the apparent link capacity to fluctuate depending on the compression efficiency. However, this situation

15   should not present a problem for lower speed links where compression efficiency is generally most important.

Thus, a method and apparatus for merging/splitting partially filled ATM cells into/from a single, merged ATM cell has been described. In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof.

20   It will, however, be clear that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

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